INTRODUCTION (2 min)

CIVIL AIR PATROL
INTRO TO SPACE
STK LESSON PLAN THREE:
PLACING A SATELLITE IN ORBIT

PP Slide 1

ATTENTION:

Now that you have a good handle of orbital mechanics and the different types of orbits, we are going to look more closely at how you place a satellite in orbit, the different launch vehicles used as boosters and various launch constraints associated with launch operations.

MOTIVATION:

It is essential you understand the conditions and constraints associated with launching a rocket, the importance the launch location will have on your orbit, and how to move a satellite's orbit once the satellite is already in space.

OVERVIEW:

1. Describe how satellites are launched into orbit
2. Understand the location advantages of the two primary US launch sites.
3. Describe the purpose of the Hohmann transfer obit.

TRANSITION: Let's now look at the orbits of satellites.

BODY (1 hour)

PRESENTATION.	
A. **PART I – OVERVIEW** 1) The purpose of this portion of the lesson plan is to provide the background on the considerations for launch. Many planning factors are involved in a launch. The lesson will specifically describe three areas: lift, booster type and launch site location.	**PP SLIDE 2**
a) **Lift** 1) A satellite requires a launch vehicle/booster to "lift" it into an orbit. Lift is achieved by a set of booster engines generating a large amount of thrust. Thrust is defined as the energy required to lift the satellite and booster mass upward and against the earth's gravitational pull. The calculations required for determining how much thrust is required to lift a booster and its payload are based upon complex formulas. However, using a simplistic explanation, you can determine how much thrust is required in the following way. First, if thrust is the amount of force required to overcome the earth's gravitational pull, then you must first determine how much gravitational force is acting upon the booster.	**PP SLIDE 3** The gravitational force is derived from the good old physics formula, W= m(g). Weight = (mass)(the acceleration of gravity) Example: To determine the gravitational force acting upon the Shuttle sitting on the launch pad, simply plug the following inputs into the above equation. Mass =140,000 slugs Acceleration =32 ft/sec/sec Thus, Weight = 140,000 slugs (32 ft/sec/sec) Weight = 4.5 million pounds. (**Note**: A slug is a unit of mass in the English system. It equals (pounds)(second)(second)/ft.) The gravitational force acting upon the shuttle is 4.5 million pounds. The launch pad exerts an equivalent upward force. As a result, the shuttle is at rest on the launch pad. If the shuttle is to lift itself into orbit, its three rocket engines and two solid rocket motors must produce enough thrust to overcome the 4.5 million pounds of gravitational force. The total engine thrust is rated for 7.7 million pounds. Thereby, the net thrust force equals 3.2 million pounds upward.

2) Booster thrust is at its greatest at liftoff. As a booster gains altitude, the thrust required to overcome gravity decreases. In other words, as the booster and satellite move away from the earth's surface, it needs less thrust to generate sufficient force to continue to move in the direction away from the earth's surface. Therefore, unsurprisingly, the gravitational force is considered a variable and not a constant and has an impact on booster design.	
3) Booster thrust requirements are optimized for the varying gravitational and aerodynamic forces encountered during the booster's ascent into space. Optimization is accomplished by designing rocket boosters with multiple stages. Each stage is designed to carry enough fuel to burn for a specified duration and to generate enough thrust to reach a specific altitude. Once a booster uses all of the fuel in a stage, it jettisons the burned out stage. Consequently, the next stage requires less thrust because of the decreasing total booster mass and the fact that gravity decreases as the booster moves away from the earth.	
b) **Booster Types** The US has six main booster types it uses to lift a satellite into space. Each booster is designed to carry a maximum payload to a specified orbit. In general, the heavier the payload weight or the greater the altitude to be achieved, the larger the booster required. The larger the booster required, the greater the associated launch cost per mission. The mission and the payload carrying capacity for each booster are described below.	
1) **Delta II**. The Delta II is a medium launch vehicle (MLV). It can carry a payload of approximately 11,000 pounds to a LEO orbit. Its mission evolved out of a DOD requirement to launch the remaining GPS satellites that were originally to be launched from the Space Shuttle. The Delta II has two versions: a 2 stage and a 3 stage booster. The 2 stage version is used for injecting a payload into a variety of low earth orbits. The 3 stage version is used for injecting a payload into a geosynchronous transfer orbit or in an elliptical orbit that goes over the poles, referred to as polar elliptical orbit.	**PP SLIDE 4**

2) **Atlas.** The Atlas booster is also a MLV. Its mission evolved as a requirement to carry communication satellites to geostationary orbit. The Atlas family has four versions: Atlas I, Atlas II, Atlas IIA and Atlas IIAS. Each version was designed to meet a primary mission of launching a payload into either LEO or GEO. Depending on many variables, the Atlas can carry a payload ranging from 4970-7950 pounds for GEO orbits and 14,500 - 19,050 pounds for LEO orbits.	**PP SLIDE 5**
3) **Titan**. The Titan booster is a three stage vehicle. Titans are considered to be heavy launch vehicles. The Titan's mission evolved out of a requirement to carry to orbit shuttle class payloads for both commercial and Department of Defense (DOD) users. There are three Titan versions: Titan II, Titan III, Titan IV. Titan is capable of placing payloads in a variety of low earth orbits or geosynchronous earth orbits. The Titan can carry 39,000 pounds to LEO and 10,000 pounds to GEO.	**PP SLIDE 6**
4) **Shuttle**. The Spaces Shuttle is also considered a satellite booster. However, unlike the previous three boosters, the satellite payload is launched into orbit from the shuttle's orbit (at approximately 150 NM altitude) rather than the ground. This provides the advantage of not having to overcome most of the earth's gravity. In its cargo bay, the shuttle can carry a 53,700 pound payload for launch into a low earth orbit.	**PP SLIDE 7**
5) **Pegasus.** As previously pointed out, to launch a satellite from ground level requires maximum lift to overcome gravity. A commercial company developed the Pegasus booster to carry small payloads that do not need the massive lift capability of a big booster. Pegasus is an air-launched booster that lifts small, 1000 pounds payloads into orbit. Pegasus works on a simple principle. The Pegasus vehicle is attached under the belly of a L-1011 carrier aircraft. The aircraft climbs to an altitude of 40,000 feet. The Pegasus booster is released and ignites after five seconds. Within 10 minutes, a LEO orbit is achieved for satellites up to 1000 pounds. The advantages of this booster system are: it is air launched so part of gravity is already overcome, and it can be launched from almost anywhere in the world so orbit orientations and safety consideration can be tailored to the launch.	**PP SLIDE 8**

6) **Taurus**. The Taurus carries 3,200 pound satellites into low earth or geosynchronous orbits. It was designed to bridge the booster capability gap between the Pegasus and the Delta. The unique feature about a Taurus rocket is that it requires very little ground support structure, reducing costs. It's launch pad is a basic cement slab	**PP SLIDE 9**
c) **Launch Locations.** 1) The second factor in planning for a successful launch is to understand the effects of launch location with respect to achieving a desired orbit. Technically speaking, you can launch from any point on earth into any orbit. But, the most cost effective method is to launch directly into the desired orbit and to use the earth's rotation as an advantage. As you remember from our Orbital Mechanics lesson, launching directly into a desired orbit is a function of many elements. Launch azimuth and launch site latitude are among those elements. The launch azimuth or the direction of the booster's flight path, determines the inclination of a satellite. Furthermore, a booster cannot launch into any orbit inclination that is less than the latitude of the launch site. Inclination is defined as the amount the orbit tilts away from the equatorial plane.	**PP SLIDE 10** **QUESTIONS:** ***1.*** *If a geosynchronous orbit in the equatorial plane is the desired orbit, the inclination of the orbit is what?* (Answer: zero). ***2.*** *To launch directly into a zero degree inclination, the launch site latitude must be what?* (Answer: zero degrees latitude) ***3.*** *The French Guiana launch site is at an optimum location for launching directly into a geosynchronous orbit.* WHY? (Answer: It is close to the equator)
2) In contrast, if an orbit is desired to go over the north and south poles, the orbit requires a greater inclination. Thus, a site at higher latitudes can be used to achieve higher inclination orbits. The Russian Tyuratam launch site is located at 51.6 degrees latitude. Consequently, a booster launched from that location could achieve a minimum satellite orbital inclination of 51.6 degrees.	

3) The earth's rotation helps to launch a satellite directly into an orbit. By launching east, the booster uses the earth's rotation to gain a little more velocity so it does not have to generate as much thrust to achieve orbit.	**QUESTION:** **4.** *Why*? (Answer: Because the Earth rotates from West to East!)
4) An additional factor the U.S. considers for launching into desired orbits is Public Law 60. Public Law 60 states that the U.S. does not launch over land masses and prefers to launch over the ocean due to safety considerations. Historically, the U.S. has launched many boosters from a variety of "overland" test ranges. However, the public safety law evolved out of a concern for technological advances in long range booster capabilities resulting in greater risk incurred by the public.	**QUESTION**: **5.** *What kind of risk are we talking about??* (Answer: The spent boosters falling on you or your house!)
5) The U.S. requires a launch capability for a variety of orbit types. Based on launch site latitude, the earth's rotation and self-imposed constraints, the U.S. has two main launch sites. *What are they?* (Cape Canaveral Air Force Station and Vandenberg Air Force Base) These launch sites and their associated constraints are depicted on this slide.	
a) Vandenberg AFB is located in California on a part of the coast that jets out into the Pacific Ocean. From this location, the U.S. can launch directly south into an orbit that goes over the north and south poles without flight over land masses. Vandenberg launches enable satellites to achieve polar orbits without violating Public Law 60.	**PP SLIDE 11**
b) Cape Canaveral, located on the U.S. east coast, provides the U.S. the capability to directly launch into non-polar, low inclination LEO orbits and equatorial GEO orbits. Due to the earth's rotation (west to east) Cape Canaveral places boosters and their payloads over the Atlantic Ocean during their liftoff and acceleration to space. The Cape Canaveral location is close to the equator.	

Because the launch site is at a 28.5 degrees North latitude, the lowest inclination a satellite can achieve is 28.5 degrees. Consequently, if a geosynchronous orbit in the equatorial plane is desired, subsequent plane change maneuvers are required.	
d) **Hohmann Transfer.** 1) A rocket booster's primary mission is to inject a satellite into a desired orbit. Often, however, the orbit initially achieved is not the final desired orbit. Thus, satellites require orbit changes in order to meet mission objectives. For example, a satellite may be launched into a low earth orbit, but requires a geosynchronous orbit to accomplish its mission. As we briefly touched upon in Orbital Mechanics, the Hohmann transfer is used to move a satellite from one orbit to another orbit. It is considered the most efficient method to alter a satellite's orbit.	**PP SLIDE 12**
2) Hohmann transfer is a two step process. It works on the principle of altering the shape of the orbit by adding velocity (energy) to increase the size of the orbit or by removing velocity (energy) to decrease the size of the orbit. To increase the orbit size, the satellite fires an on-board booster for a period of time. This firing of the on-board booster occurs at perigee. Perigee is defined as the point in the satellite orbit closest to the earth. The positive energy change causes the satellite to move into a highly elliptical orbit. As the satellite passes through apogee the point in its orbit when it is the farthest from earth, a second firing of the onboard booster is required. This firing gives the satellite more positive energy changing an elliptical orbit to a circular orbit. In other words, it increases the perigee of the orbit and makes it the same as the apogee to achieve a circular orbit. Once the two burns are complete, a final orbit is achieved.	**PP SLIDE 13**

B. **PART II - STK SCENARIOS**

This portion of the lesson plan illustrates the launch concepts you have learned about in part one. To do this, you will run two self-guided scenarios using STK/VO software. Each scenario will help you visualize the major concepts you have just seen.
The instructions below are a step-by-step guide to help you load, view, and understand the scenarios.

REFER TO CHAPTER THREE, PART II - FOR STK SCENARIOS ONE AND TWO AT ATTACHMENT

Recommend handing out the attachments to the students and let them accomplish the scenarios at their own pace.

C**. PART III - STUDENT PROBLEM**

This portion of the lesson plan provides an opportunity for you to apply the concepts you have learned in Part I and Part II by solving a problem.

PROBLEM

The problem is to generate an initial launch of an actual Delta mission, SKYNET 4D. To run the scenario, complete the following steps:

1. Select **CREATE NEW SCENARIO** on the **START UP FOR APPLICATION-STK** window.

2. Select **STK WINDOW** at the bottom of the viewer.

3. Select the **CREATE NEW LAUNCH VEHICLE** from the ICON bar on the left side.

4. Select **PROPERTIES** and then **BASIC**. Under the **TRAJECTORY TAB**, enter the following parameters.

a. step size:	10.0 seconds
b. launch latitude:	28.5 degrees
c. launch longitude	-81.0 degrees
d. launch altitude	100.0 feet
e. burn out latitude	-1.0 degrees
f. burnout longitude	-19.0 degrees

(Continued on next page)

Proposed Solution There is no 'solution' per se, this was more of a demonstration of launch considerations.	5. Select **APPLY,** then **OK.** 6. Toggle to **EARTH MAP** and select **START**. Watch SKYNET 4D Mission liftoff from CCAFS. 7. To exit, select **X** When the **CONFIRM WINDOW** appears, select **OK**. It will exit you out of the STK program.
D. **PART IV - SUMMARY** In the launch lesson, you have learned about lift, boosters, and launch location. Each influences the satellite's ability to achieve a desired orbit. First, launch boosters are designed to carry a specified payload weight. To lift a satellite to its desired orbit, the booster must generate sufficient thrust to overcome the earth's gravitational pull acting on the launch booster. Second, you have learned about the effects of launch site location in determining the inclination of an initial orbit. Finally, due to various launch constraints, the initial satellite orbit is not usually the final desired orbit. Consequently, it requires a plane change by conducting a Hohmann transfer process. **TRANSITION:** Are there any questions?	
BREAK !! You have completed Scenario Three.	